Synopsis

Ph.D. in Special Education

Developing Computer Assisted Cartesian Plane to Enhance Graph Skills of Students with Visual Impairment

Investigator

B. Rajeswari

Reg No: 16PHSEP001

Supervisor

Dr.G.Victoria Naomi

Professor & HOD

Department of Special Education

Submitted to

Avinashilingam Institute for Home Science and Higher Education for Women

Coimbatore

August 2021

I. Introduction

In Mathematics, a graph is defined as a chart with statistical data, which are represented in the form of curves or lines drawn across the coordinate point plotted on its surface. Graphs are widely prevalent as part of a learning curriculum in all school subjects. Graph literacy is the ability to identify important features of graphs and relate those features to the context of the graphs. It is an important skill to master STEM (Science, Technology, Engineering and Mathematics) subjects. Cartesian Plane is a graph with two perpendicular number lines used to describe any point in the Plane using an ordered pair of numbers. The horizontal line is referred as 'x' axis and the vertical line referred as 'y' axis and the intersection of both lines is called as Origin. A Cartesian graph is one that shows numerical relationships by drawing points, lines, curves, or geometric shapes on the Cartesian Plane. Traditionally Tactile graphs are the learning mediums for learning graphs to visually impaired students. While graphing principles can be represented using this medium, producing Tactile graphs requires specialized equipment and knowledge about how to effectively convey graph components through Tactile means. It includes push-pins and rubber bands on foam boards, specialized building blocks imprinted with Braille, and embossed paper graphs. The consideration when using Tactile graphs with students with visual impairment is ensuring that the information is presented in a comprehensible way, especially it has multiple parts and labels. This means that care must be taken when producing these Tactile graphs. Lack of access to graphical materials significantly impacted study and career choices of vision-impaired students.

In the era of Science and Technology, visually impaired children need to understand the basics of mathematics in order to play a role in society well. (Sanchez & Flores, 2004). Therefore, visually impaired children need help to overcome these obstacles so that children can learn independently (McCarthy & Shelvin, 2017;Tiofan, Tolle, & Amalia, 2017). One solution to overcome this problem is by utilizing the development of the technology called Assistive Technology. A number of other technologies for providing accessible graphics have been developed in the last decade, although none are yet in widespread use. These include sonification (e.g., Brown & Brewster, 2003); haptic feedback (e.g., Darrah, 2013) and integrated eBook delivery on touch screen (Goncu & Marriott, 2015) and 3D-printed Tactile models (e.g., Grice, Christian, Nota, & Greenfield, 2015; Kolitsky, 2014)

Keeping the need in mind, an initiative was taken in this study to develop Computer Assisted Cartesian Plane to enhance graph skills and study its efficacy by introducing the software system to visually impaired students in plotting and Finding Points in the Cartesian Plane and to assess their performance in its application.

II. Review of Literature

Benjamin K. Davison (2012) in his study on "Understanding How Visually Impaired Students Demonstrate Graph Literacy with Accessible Auditory Graphs" found that blind adults can use mice for point estimation, building a system that could answer questions based on the standards and evaluated the system in classroom and testing situations.

Benjamin K. Davison (2013) in his study on "Universal Graph Literacy: Understanding How Blind and Low Vision Students can satisfy the Common Core Standards with Accessible Auditory graphs" found that active point estimation with sonification enables people to solve graphing problems, regardless of their visual impairment. He also has shown that active point estimation with sonification is possible, relates to graphing standards in the sixth grade common core standards for mathematics and has similar benefits as paper formats.

III. Rationale for the Study

Mathematics education is easily accessible to fully sighted children and it is less accessible to students with vision impairment since many of its concepts are presented graphically, and there are many concepts that cannot be explored by touch and are put across through visual observation. (Design Science 2011; Kalra et al. 2009; Maguvhe 2005; Sahin & Yorek 2009). The curriculum in regular schools is also designed for fully sighted children and is delivered largely through sight related tasks. Acquisition of mathematical skills can be more difficult for students with visual impairments due to the abstract nature of many essential concepts and the highly visual presentation of the subject (Kapperman, Heinze & Sticken, 2000).

The most difficult mathematics lessons learned by visually impaired children are materials that require more visual observation, such as a two-dimensional figure, three-dimensional figure, circumference and volume (Nurmitasari, 2015). These materials make the visually impaired children have more difficulty than other materials, although they also experience difficulties in learning other materials. Students with visual impairment should not be left from learning a graph concept due to lack or limited vision. Not only they can graph with the right tools, they can often do so better than their sighted peer (Kumar et.al 2001). Children who are visually impaired should learn mathematical skills at the same level as their sighted peers (Tindell, 2006).

Schweikhardt (2000) noted that requirements for the successful integration of students who are visually impaired into general-education mathematics environments include notation that is simultaneously accessible by both people who are Braille readers and those who are print readers. Educators have made coordinate graphs a core component of secondary mathematics education. The emphasis of graphic literacy can be seen in many education standards. The Cartesian Plane of 'x' and 'y' works in many real life situations. For example, if one wants to plan where to place different pieces of furniture in a room, the person can draw a two dimensional grid and use an appropriate unit of measurement. Hence the concept of Cartesian Plane is vital to any learner. Students with visual impairment should know how to plot coordinates of points and locate its position in the Cartesian Plane. As mentioned, Graphs are taught to visually impaired students using Tactile graph which consumes time, planning and in nutshell a tedious process.

In today's context, the technology boom has produced an abundance of tools to assist with learning and teaching, including those useful to teachers of students who are visually

impaired. High-quality teaching incorporates tools to help students with and without visual impairment to access and understand advanced mathematics to the best of their ability. Often, itinerant teachers/Special teachers to the visually impaired students may have only one Braille reader in their entire careers and will have very little time to tackle a trial and-error approach to teaching such students (Zhou, Parker, Smith, & Griffin Shirley, 2011). For a classroom teacher who has a student who is visually impaired, the presence of technology in the classroom is not optional but necessary. Many mathematicians, such as Buteau, Marshall, Jarvis, and Lavicza (2010), believe proficiency in advanced mathematics has become synonymous with proficiency in corresponding technology. Technology can eliminate the tediousness of calculations, allowing students to focus more on conceptual understanding. Students who are visually impaired must have access to technology that provides these same supports.

With this premise, a survey of literature related to technology based Cartesian Plane was explored in Indian Context. It was hardly available. Hence this investigation was focussed to develop Computer Assisted Cartesian Plane to enhance graph skills of students with visual impairment and the effect of this newly developed software system for Cartesian Plane was examined with the help of student's participation and performance in plotting and Finding Points in this Experimental study.

IV. Statement of the Problem

The statement of the problem is worded as: ***Developing Computer Assisted Cartesian Plane to Enhance Graph Skills of Students with Visual Impairment***

V. Objectives

The objectives of the study were to:

1. Develop Computer Assisted Cartesian Plane to enhance graph skills of students with visual impairment.
2. Find out the level of acquisition of Basic Concepts related to Cartesian Plane among visually impaired students before and after intervention.
3. Compare mean scores of Plotting Points on Quadrants and Axes with respect to Tactile Cartesian Plane (Pretest) and Computer Assisted Cartesian Plane.
4. Compare mean scores of Finding Points on Quadrants and Axes with respect to Tactile Cartesian Plane (Pretest) and Computer Assisted Cartesian Plane.
5. Compare mean scores of Plotting Points on Quadrants and Axes with respect to Tactile Cartesian Plane (Posttest) and Computer Assisted Cartesian Plane.
6. Compare mean scores of Finding Points on Quadrants and Axes with respect to Tactile Cartesian Plane (Posttest) and Computer Assisted Cartesian Plane.
7. Compare mean scores of Finding Points on Axes with respect to Tactile Cartesian Plane and Computer Assisted Cartesian Plane.
8. Study the influence of Gender on Plotting Points on Quadrants and Axes while using Tactile Cartesian Plane in the Pretest & Posttest and Computer Assisted Cartesian Plane.

9. Study the influence of Gender on Finding Points on Quadrants and Axes while using Tactile Cartesian Plane in the Pretest & Posttest and Computer Assisted Cartesian Plane.
10. Study the influence of Grade on Plotting Points on Quadrants and Axes while using Tactile Cartesian Plane in the Pretest & Posttest and Computer Assisted Cartesian Plane.
11. Study the influence of Grade on Finding Points on Quadrants and Axes while using Tactile Cartesian Plane in the Pretest & Posttest and Computer Assisted Cartesian Plane.

VI. Hypotheses

The null hypotheses selected for the study are:

1. There is no significant difference in the level of acquisition of Basic concepts related to Cartesian Plane among visually impaired students before and after intervention.
2. There is no significant difference in the mean scores of Plotting Points and Finding Points on Quadrants and Axes with respect to Tactile Cartesian Plane before and after intervention.
3. There is no significant difference in the mean scores of Plotting Points and Finding Points on Quadrants and Axes with respect to Tactile Cartesian Plane used in Pretest and Computer Assisted Cartesian Plane.
4. There is no significant difference in the mean scores of Plotting Points and Finding Points on Quadrants and Axes with respect to Tactile Cartesian Plane used in Posttest and Computer Assisted Cartesian Plane.
5. There is no significant difference in the mean scores of Plotting Points on Quadrants and Axes while using Tactile Cartesian Plane in Pretest & Posttest and Computer assisted Cartesian Plane.
6. There is no significant difference in the mean scores of Finding Points on Quadrants and Axes while using Tactile Cartesian Plane in Pretest & Posttest and Computer assisted Cartesian Plane.
7. There is no significant influence of Gender on Plotting Points and Finding Points on Quadrants and Axes while using Tactile Cartesian Plane in the Pretest & Posttest and Computer Assisted Cartesian Plane.
8. There is no significant influence of Grade on Plotting Points and Finding Points on Quadrants and Axes while using Tactile Cartesian Plane in the Pretest & Posttest and Computer Assisted Cartesian Plane.

VII. Method

The method of the present study has two stages

Stage 1: Design and Development of Computer Assisted Cartesian Plane

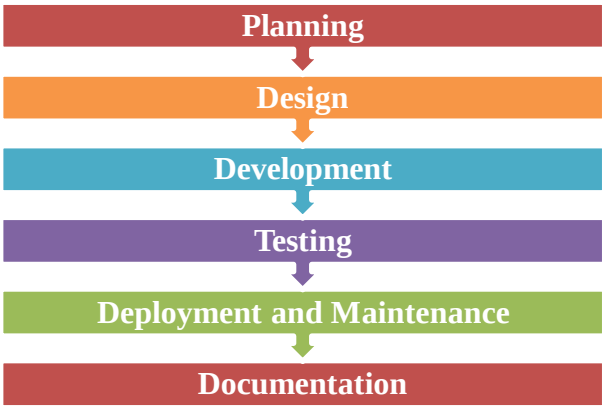
Stage 2: Study the effectiveness of Computer Assisted Cartesian Plane

i. Stage I: Development of Computer Assisted Cartesian Plane

Computer Assisted Cartesian Plane has been developed using the language called Visual basic. The "Visual" part refers to the method used to create the graphical user interface (GUI). The "Basic" part refers to the BASIC (Beginners All-Purpose Symbolic Instruction Code) language, a language used by more programmers than any other language in the history of computing.

a. Life Cycle of Development of Computer Assisted Cartesian Plane

The life cycle of Computer Assisted Cartesian Plane development explains the process of developing the software tool for visually impaired students. Life cycle process deals with 6 phases. They are listed below.



1. Planning: This phase describes the planning of requirements of entire Computer Assisted Cartesian Plane development. It involves the objective of designing Computer Assisted Cartesian Plane, User requirements, Official and non-official requirement which includes Stationary items, Manpower involved, Time taken to complete the Computer Assisted Cartesian Plane, Budget for developing Computer Assisted Cartesian Plane, Possible Occurrence of Errors while developing Computer Assisted Cartesian Plane and Required Software for implementation. The time taken for planning phase was one month.

2. Design: In this phase, prototype of Computer Assisted Cartesian Plane tool or blueprint of Computer Assisted Cartesian Plane was designed. This shows how the end product looks like. This phase involved the designing of Pseudo code and algorithm, Flow chart, Input and Output window Blueprint, Module, Variables analysis, Class/Object diagram.

3. Development: In this phase, the Computer Assisted Cartesian Plane software was developed. The development team overviewed the design performed in designing phase. Through this, each module has been developed individually. The software used to implement Computer Assisted Cartesian Plane is Visual Basic 6.0. Development of the software system took 2 months of time.

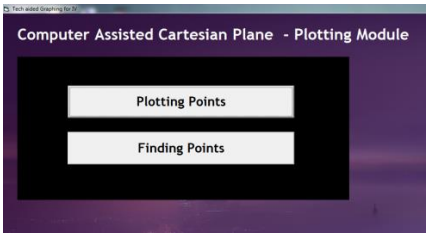
4. Testing: This testing phase is necessary in order to free from bugs and errors. The software has to work in all situations without any errors. Integrated testing was performed for the entire tool to check for error. In the occurrence of error, the identified error was corrected and again testing was performed. The process was repeated until the developed Computer Assisted Cartesian Plane tool has become error free. This phase consumed one month time duration.

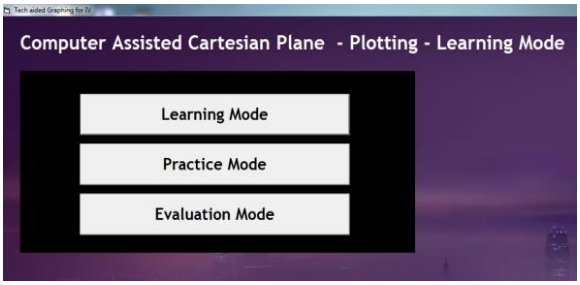
5. Deployment and maintenance: Once the Computer Assisted Cartesian Plane tool was developed, the developed system was open to the students with visual impairment for usage. A feedback was gotten from the students regarding their ease of use, difficulties and future enhancement. Based on that, the tool was modified. Since it is an iterative process it took two months for iteration which includes testing.

6. Documentation: Documentation here means documenting the entire Computer Assisted Cartesian Plane tool in text and images.

b. Module description of Computer Assisted Cartesian Plane

The entire software is divided into two modules namely Plotting Points and Finding Points.

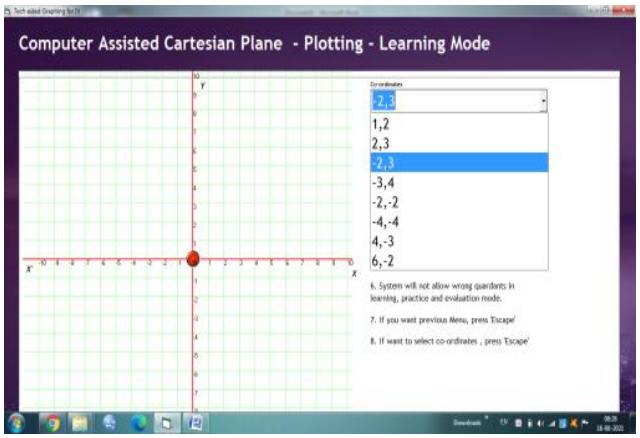




Further each of these modules has three sub modules namely Learning, Practice and Evaluation. The modules have been developed individually and clubbed together finally to make the software as a single unit.

1. Execution Window

For all the modules the execution window is split into two columns. On the left side working area of graph is there. On the other side instructions are displayed. There is a drop down box available on the right side either to select the readily available coordinates or the user can give the input. Once the coordinates are selected or given the software analyzed the quadrant and to fix the point internally based on the values of x and y axis. This helps the avoidance of movement beyond the axis points done by the visually impaired student.



2. Keys Used

Limited numbers of keys were used to operate the Computer Assisted Cartesian Plane. The following are the keys selected for the entire operation of Computer Assisted Cartesian Plane.

S.No	Keys Used		Operation
1.	Shift		For selection. Similar to ENTER key option
2.	Esc		Go back to the Previous Menu
3.	Up arrow		Moving towards positive values of y axis
4.	Down arrow		Moving towards negative values of y axis
5.	Right arrow		Moving towards positive values of x axis
6.	Left arrow		Moving towards negative values of x axis
7.	Number Key		To type the coordinates
8.	Comma key		To separate the coordinates

Other than these, the common keys such as Delete key and Backspace keys to delete when it is wrongly typed and to adjust the space were used.

3. Time Complexity

Time complexity is the period of time taken by the software to perform its action. It is also called as computational complexity. It is determined by counting the number of operations involved in the algorithm.

S.No	Complexity case	Time Complexity
1.	Best case	N log N
2.	Average case	N log N
3.	Worst case	O (N^2)

c. Pilot Study

When the device was ready to use, Pilot study was conducted among 10 visually impaired students studying at Inclusive Schools in Coimbatore District. Pretesting and post testing were conducted in a sequence. Adequate modifications in the tool were made after Pilot Study.

ii. Stage 2: Study the effectiveness of Computer Assisted Cartesian Plane

After development of the Computer Assisted Cartesian Plane, its efficacy was analysed with the introduction of the software. For this purpose, samples have been selected and the procedure for finding out the effectiveness of the software is detailed below.

a. Selection of the Sample

The sample comprised of 42 visually impaired students with 22 boys and 20 girls from Grade IX to XII studying in 26 Higher Secondary Schools in Coimbatore District.

b. Design of the Study

The design adopted in the study is Quasi Experimental design. It is a single group design. Here Pre observation and post observation were made besides treatment. The layout of the design is: $\mathbf{O_1 \times O_2}$. Here $\mathbf{O_1}$ is Pre observation and $\mathbf{O_2}$ is post observation and × is the treatment in the Experimental study.

c. Variables

1. Independent variable

1. Development of Computer Assisted Cartesian Plane
2. Gender: Boys and Girls
3. Grade: IX to XII

2. Dependent Variable

a. Performance of students in Tactile Cartesian Plane and Computer Assisted Cartesian Plane.
b. Rating of the software system by Special Teachers and Student Teachers.

d. Construction of the Tool

1. Personal Data Bank

To collect general information regarding Gender, Grade and Name of the School personal data bank was developed.

2. Tool to assess the level of acquisition of Basic Concepts related to Cartesian Plane

This involves 14 questions related to Axes, Origin, Quadrants, Forms of Quadrants, Location of Positive and Negative Values in Axes.

3. Assessment of performance of Plotting Points and Finding Points on the Cartesian Plane with respect to Tactile Cartesian Plane and Computer Assisted Cartesian Plane

The test was aimed to measure the performance of students on Plotting and Finding Points on the Cartesian Plane. Sixteen questions were selected from the two concepts viz. Plotting Points and Finding Points. Questions related to Finding and Plotting Points located on Quadrant and Axes were included.

Scoring: For each correct response one score and zero score for incorrect response.

4. Measuring internal Consistency of Tool

A questionnaire related to Computer Assisted Cartesian Plane was developed. It is in the form of 4 point rating scale viz Strongly Agree, Agree, Disagree and Strongly Disagree.

e. Intervention strategies

The investigator developed 10 Tactile Cartesian Plane, since one Tactile aid can be used for only 4 to 5 students. The Tactile Cartesian Plane has been prepared using Graph Sheet, Twin Thread, Woolen Thread, Cardboard, Glass Liner, Push Pins, Cello Tape and Glue. The preparation time for making 10 Tactile Cartesian Plane took 20 hours.

a. Intervention in the use of Tactile Cartesian plane

Students were trained in the concepts such as 'x' axis, 'y' axis, Origin, Quadrants, Form of Quadrants, Units and Location of Positive and negative Values in Axes.

1. Intervention on Plotting Points on Quadrants

Students were introduced about the concepts of coordinates on Plotting it on Quadrants. For example. Plot the points (5, 4) and (-2, 7). Practice has been given to plot coordinates on the four Quadrants.

2. Intervention on Plotting Points on Axes

Students were introduced about the concepts of coordinates on Plotting it on Axes. For example. Plot the points (4, 0) and (0,-3). Practice has been given to plot coordinates on the four Axes.

3. Intervention on Finding Points on Quadrants

Students were introduced about the concepts of coordinates on Finding it on Quadrants. For example. Find the points (4, 5) and (0,-3). Practice has been given to find coordinates on the four Quadrants.

4. Intervention on Finding Points on Axes

Students were introduced about the concepts of coordinates on Finding it on Axes. For example. Find the points (0, 5) and (-6, 0). Practice has been given to find coordinates on the four Axes.

b. Application of Computer Assisted Cartesian Plane

The students were instructed to switch on the device they possess (Computer / laptop). The students who did not have the device, the investigator has given her own device for use. A demonstration was given on Computer Assisted Cartesian Plane which has voice over with minimal Computer key usage. Then the students were oriented on the keys used, voice over, beep sound, and selection of keys for particular operation.

A step by step procedure of operating Computer Assisted Cartesian Plane in learning Plotting Points and Finding Points on Cartesian Plane was demonstrated and the students were asked to operate on their own. After the students were trained in the learning of Plotting and Finding Points on Cartesian Plane, they were given practice time to Plot and Find points.

This phase consume a period of 4 months. An average of 6 hours required for a student / a group of 2-3 students for learning and practice.

f. Data Collection Procedure

Phase I

An assessment was made on two aspects namely performance on Plotting and Finding Points on Cartesian Plane using Tactile Cartesian Plane. This test was considered as pretest using Tactile Cartesian Plane. The time duration taken for assessment of performance of students using Tactile Cartesian Plane was one month.

Phase II

An assessment was made on two aspects namely performance on Plotting and Finding Points on Cartesian Plane using Tactile Cartesian Plane after intervention. This test was considered as Tactile posttest. An assessment was made on two aspects namely performance on plotting and Finding Points on Cartesian Plane using Computer Assisted Cartesian Plane. This test was considered as performance using Computer Assisted Cartesian Plane. The time duration taken for assessment of performance of students using Tactile Cartesian Plane was one month and students' performance in Computer Assisted Cartesian Plane was another one month and thus making a total of 2 months duration for this assessment. For all the 3 tests viz Tactile Pretest, Tactile Posttest and Computer Assisted Test, the tool (question) used was the same.

VIII. Major Findings of the Study:

a. Findings related to the features of Computer Assisted Cartesian Plane

1. The Computer Assisted Cartesian Plane uses only 8 keys with simple operation.
2. Computer Assisted Cartesian Plane software system is error free.
3. Computer Assisted Cartesian Plane once developed can be used to 'n' number of times and 'n' number of students for Plotting and Finding Points as against Tactile Cartesian Plane which may be used for limited number of times and limited number of students.

b. Findings related to Effect of Computer Assisted Cartesian Plane

1. Pertaining to the analysis of the acquisition of basic concepts before and after intervention, the scores after intervention (M=12.40) is significantly higher than the score before intervention (M=3.29).
2. It was found that Posttest score using Tactile Cartesian Plane (M=23.05) is higher than the pretest score using Tactile Cartesian Plane (M=4.76).
3. The result revealed that the performance of student using Computer Assisted Cartesian Plane (M=23.05) is higher than the Tactile Cartesian Plane used in the pretest (M=4.76).

4. It was found that the scores of student in Computer Assisted Cartesian Plane and in the Tactile Cartesian Plane after intervention were at the same level.
5. The score obtained in Computer Assisted Cartesian Plane in Plotting Points on Quadrants (M=3.07) is higher than the scores obtained in Tactile Cartesian Plane in the Pretest (M=0.76). It was found that the posttest score obtained in Tactile Cartesian Plane and the score of Computer Assisted Cartesian Plane were at the same level.
6. The score obtained in Computer Assisted Cartesian Plane in Plotting Points on Axes (M=2.64) is higher than the scores obtained in Tactile Cartesian Plane in the pretest (M=0.05). The scores of Tactile Cartesian Plane obtained in the post test and the scores of Computer Assisted Cartesian Plane were found to be to the same extent.
7. The score obtained in Computer Assisted Cartesian Plane in Finding Points on Quadrants (M=2.76) is higher than the scores obtained in Tactile Cartesian Plane in the pretest (M=0.60). Though the mean of Computer Assisted Cartesian Plane is higher (M=2.76) compared with the mean of Tactile Cartesian Plane (M=2.50), the difference is not significant.
8. The score obtained in Computer Assisted Cartesian Plane to Finding Points on Axes (M=2.29) is higher than the scores obtained in Tactile Cartesian Plane in the Pretest (M=0.07). The performance of students in Computer Assisted Cartesian Plane and Tactile Assisted Cartesian Plane in the Posttest seem to be at the same level.
9. The study revealed that there is a no significant influence of Gender in performing Plotting and Finding Points in Quadrants and Axes using both Tactile Cartesian Plane and the Computer Assisted Cartesian Plane. Hence Gender seems to be independent of its own.
10. The study reported that there is no significant influence of Grade in performing Plotting and Finding Points in Quadrants and Axes using both Tactile Cartesian Plane and the Computer Assisted Cartesian Plane. Hence Grade seems to be independent of its own.

IX. Scope of the Study

1. Computer Assisted Cartesian Plane has universal design feature and thus be useful to any learner.
2. Computer Assisted Cartesian Plane once developed, can be used ‘n’ number of times and by ‘n’ number of learners.
3. Computer Assisted Cartesian Plane has three modes namely Learning, Practice and Evaluation and thus has holistic software system.
4. It can be used on offline mode and does not require internet facility.
5. Computer Assisted Cartesian Plane has scope for further development of advanced software system for mathematical concepts.

X. Delimitations

The following were the delimitations of the study:

1. The present investigation being an Experimental study was confined to 42 samples.
2. The study was confined to only Coimbatore district in Tamil Nadu

3. The study was confined to students with total vision impairment.

XI. Conclusion

This Computer Assisted Cartesian Plane helps students with visual impairment to induce their performance in Plotting and Finding Points. The future scope of the study is to draw line graphs and advanced mathematical concepts using Computer Assisted Cartesian Plane.

References

1. Tiofan, L. T., Tolle, H., & Amalia, F. (2017). Rancang Bangun Aplikasi Messaging Berbasis Voice Interaction Bagi Penderita Tunanetra Pada Sistem Operasi Android. Jurnal Pengembangan Teknologi Informasi Dan Ilmu Komputer, 1(7), 620-627
2. Akpan, J., & Beard, L. (2014). Assistive Technology and Mathematics Education. Journal of Educational Research, 2(3), 219- 222.
3. McCarthy, P., & Shevlin, M. (2017). Opportunities and challenges in secondary education for blind/vision impaired people in the Republic of Ireland. Disability and Society, 32(7), 1007-1026. https://doi.org/10.1080/09687599.20 17.1337564
4. Sanchez, & Flores. (2004). Audio Math: Blind Children Learning Mathematics Through Audio. In 5th Intl Conf. Disability, Virtual Reality & Assoc. Tech., Oxford, UK (p. 184).
5. Darrah, M. A. (2013). Computer haptics: A new way of increasing access and understanding of math and science for students who are blind and visually impaired. *Journal of Blindness Innovation and Research, 3*(2). Retrieved from https://nfb.org /images/nfb/publications/jbir/jbir13/jbir030202abs.html.doi: http://dx.doi.org/10.524 1/3-47
6. Goncu, Cagatay & Marriott, Kim. (2015). Creating eBooks with Accessible Graphics Content. 89-92. 10.1145/2682571.2797076.
7. Grice, Noreen & Christian, Carren & Nota, Antonella & Greenfield, Perry. (2015). 3D Printing Technology: A Unique Way of Making Hubble Space Telescope Images Accessible to Non-Visual Learners. Journal of Blindness Innovation and Research. 5. 10.5241/5-66.
8. Maguvhe, Mbulaheni. (2015). Teaching science and mathematics to students with visual impairments: Reflections of a visually impaired technician. African Journal of Disability. 4. 10.4102/ajod.v4i1.194.
9. Kalra, N., Lauwers, T., Dewey, D., Stepleton, T. & Dias, M.B., (2009), 'Design of a braille writing tutor to combat illiteracy', Information Systems Frontiers 11(2), 117-128. http://dx. doi.org/10.1007/s10796-009-9171-2
10. Kumar, D., Ramasamy, R. & Stefanich, G. (2001), 'Science for students with visual impairments: Teaching suggestions and policy implications for secondary educators', Electronic Journal of Science Education 5(3), 1-4.
11. Sahin, M. & Yorek, N., (2009), 'Teaching science to visually impaired students: A small scale qualitative study', US-China Education Review 6(4), 19-26.

12. Design Science, (2011), New math to speech technologies to help blind and visually impaired students master mathematics, viewed 22 June 2015, from www.dessci. com/en/company/press/releases/110524.html
13. Osterhaus, S., (2002), Susan's math technology corner: Teaching a blind student how to graph on a coordinate plane: No tech, low tech, and high tech tools, viewed 14 January 2015, from http://www.tsbvi.edu/math/graphing.htm
14. Kapperman, Gaylen & Sticken, Jodi & Heinze, Toni. (2002). Survey of the use of Assistive Technology by Illinois Students who are Visually Impaired. Journal of Vision Impairment and Blindness. 96. 10.1177/0145482X0209600205.
15. Nurmitasari. (2015). Pola Penerimaan Siswa Tunanetra Dalam Pembelajaran Matematika Di SMPLB. Journal e-DuMath, 1 (2), 82-88.
16. Tindell, M. (2006, Summer). Technology and life skills: A beginner's guide to access technology for blind students. *Future Reflections*, *25*(2). Remmmmmmjtrieved from http://www. nfb.org/ images/nfb/publications/fr/fr22/fr06sum09.htm
17. Schweikhardt, W. (2000). Requirements on a mathematical notation for the blind. In R. Vollmar and R. Wagner (Eds.), Computers Helping People with Special Needs, ICCHP 2000: Proceedings of the 7th International Conference on Computers Helping People with Special Needs, July 17-21, 2000 (pp. 663- 670). Wien, Austria: Österreichische Computer Gesellschaft [Austrian Computer Society]
18. Zhou, Li & Parker, Amy & Smith, Derrick & Griffin-Shirley, Nora. (2011). Assistive Technology for Students with Visual Impairments: Challenges and Needs in Teachers' Preparation Programs and Practice. Journal of Visual Impairment and Blindness. 105. 197-210. 10.1177/0145482X1110500402.
19. Buteau, Chantal & €, Neil & Jarvis, Daniel & Lavicza, Zsolt. (2010). Integrating computer algebra systems in post-secondary mathematics education: Preliminary results of a literature review. International Journal for Technology in Mathematics Education. 16.